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Western Hemisphere Natural Rubber*

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In 1940 the United States imported some 818,000 long tons of rubber, valued at $318,000,000. Of this amount 650,000 long tons were used within the country. Ninety-seven percent of this rubber came from the Far East. The outbreak of war in the Pacific and the subsequent loss by the Allied Nations of Malaya and the East Indies thus deprived us of the main source of a strategic material, the indispensability of which, already familiar, has loomed larger with each day of war. By the time war came the seriousness of the rubber situation had begun to be realized and certain steps were taken to meet the crisis. These steps were along two different approaches—the building of a synthetic rubber industry, and the development and exploitation of sources of natural rubber within the Western Hemisphere.

The construction of four 2500-ton capacity, government-owned synthetic rubber plants was authorized in 1941. Around this nucleus has been built the industry which it is estimated will produce some 800,000 tons of synthetic rubber in 1944.

The history of the development of synthetic rubber is almost as long as the period of commercial utilization of rubber. An outline of the early steps is given by H. & R. Wolf (1936). There had been several attempts to analyze rubber in the early 19th century, none of them very revealing. Then in 1860 Greville Williams isolated a low-boiling point fraction which he named *isoprene*. From this isoprene Williams was able to build up, by polymerization, a substance having some of the properties of rubber. Several other investigators subsequently pointed out the apparent relation between isoprene and rubber and by 1880 the production of isoprene from simple materials was thought to be the only step necessary to make the production of synthetic rubbers practical. Between 1882 and 1884 a process for the manufacture of isoprene from turpentine was perfected. The step from isoprene to a rubber-like compound proved too time-consuming, however, until in 1910 it was found that sodium metal would bring about polymerization. In that year the manufacture of isoprene rubber from methyl isoprene produced from acetone with the aid of sodium was begun in Germany.

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Between 1910 and 1941 much progress was made on the problems of producing synthetic rubbers. Various sources of isoprene were investigated and chloroprene, butadiene, and other compounds for use instead of isoprene were developed. Facts were learned about the polymerization of these materials and co-polymerization with other hydrocarbons.

The point to be understood is that synthetic rubber is no eleventh hour miracle developed in response to the war emergency. The conditions imposed by war have accelerated certain phases of synthetic rubber development, but the underlying facts have been accumulated over a long period of time. Knowing this, one is more inclined to appreciate the many difficulties that have been involved in the manufacture of satisfactory synthetic rubber. Monumental progress has been made toward overcoming these difficulties, and in constructing and putting into operation plants for the production of synthetic rubbers. The final answer has not yet been obtained. Hundreds of chemists are working on the problems and continued improvement in quality and usefulness may be expected. Up to the present, however, the production of synthetic rubber has not alleviated the critical need for natural rubber.

It is perhaps worth mentioning here that actually there is no such thing as synthetic rubber. If there were there would probably be no need for natural rubber. So-called synthetic rubbers are substances having some of the essential physical properties of rubber, but none of the synthetics has the chemical structure of rubber and none has all of its physical properties. There are many types of synthetic *elastomers* or *plastomers*. A synthetic elastomer, to be designated as synthetic rubber, must be a substance capable of vulcanization and after vulcanization must stretch to at least four times its normal length and then resume its original length forcibly and rapidly when the pressure is released. GR-S, or the Buna type, synthetic has this property, but in going through the procedure generates vastly more heat than natural rubber. It is this factor which limits its use in tires where there is rapid flexing.

Large amounts of natural rubber are needed for combining with the synthetics in the manufacture of larger size truck and bus tires. Many uses still demand pure natural rubber. When these facts are considered in the light of the daily growing demands for both military and civilian products made of rubber, the necessity of increasing our supplies of natural rubber is highlighted.

Attempts to increase and assure our supply of natural rubber have been three-fold and all were initiated in 1940. Agreements were made with several of the Tropical American countries whereby the United States government undertook, through an official agency, to guarantee the price of crude rubber over a fairly long period—in most cases extending to 1946. This move was aimed at stimulating the collection of rubber from *wild* trees in Central and

South America. A correct estimate of the number of such trees and the amount of rubber that could be obtained from them would be very difficult to make. Published guesses have indicated as many as 300,000,000 trees, a probably fantastic figure, with an attainable yield of 50,000 tons of rubber annually, but there are many serious complications involved in the collection of this wild rubber in large quantities.

Cooperative arrangements have been made with 14 of the Latin American countries for the development of rubber plantations. These plantations have the double aim of increasing the available supply of rubber during the present emergency if it is prolonged and assuring a dependable Western Hemisphere supply of rubber in the future. A summary of the plan for establishing a self-sustaining rubber-growing industry has been published by Brandes (1941).

In addition all plants holding any promise of being useful in providing a domestic source of rubber are being thoroughly investigated.

Hevea brasiliensis. The most important source of rubber is *Hevea brasiliensis,* the Para rubber tree. This tree, apparently long known to the South and Central American Indians, made its first appearance in white man's records in the early 18th century.

In 1770 Priestley discovered that rubber, in this case from India, would erase pencil marks, hence the name *rubber* and the persistence of the term *India rubber* even after the majority of our rubber came from a South American tree. In 1823 Charles McIntosh found that rubber is soluble in benzene. This discovery broadened the uses for waterproofing as previously only freshly collected latex could be used for coating cloth.

In 1839 Goodyear came accidentally upon the knowledge that rubber could be vulcanized by mixing with sulphur and heating. This resulted in an elastic material which did not become sticky in hot weather and could stand much lower temperatures than crude rubber without becoming brittle. An amazing number of uses were immediately found for the vulcanized product. The demand rose so rapidly that whereas in 1849 rubber was collected from *Hevea brasiliensis* only in the vicinity of the city of Para, in 1850 some 25,000 people were concerned in its collection in the State of Para alone, and collectors had ascended far up the tributaries of the Amazon. As the uses of rubber increased it was collected in varying amounts from many different plants but the Para rubber tree remained the most important, except perhaps for a brief period just after the turn of the century when guayule became a very large producer.

In 1876 Henry Wickham, later knighted in consideration of his contributions to the British Colonial interests, took seeds of *Hevea brasiliensis* from the Amazon region to Kew. He then introduced the tree, using Kew-grown material, into India, Ceylon, the Straits Settlements, and the Dutch East

Indies. There followed an amazing development of the rubber plantations in the East, paralleled by the nearly complete abandonment of the rubber production industry in the Western Hemisphere.

The latent danger in the complete dependence of the United States on eastern rubber supplies gave rise to governmental action in 1940 when a bill was passed by Congress authorizing expenditure of a half million dollars for investigations directed toward the development of rubber production in the Western Hemisphere. The Bureau of Plant Industry was charged with the conduct, in cooperation with other agencies, of these investigations.

The first step was a survey of the Western Hemisphere areas falling within the range to which *Hevea* is adapted, or in other words between the equator and about 20° of latitude. Simultaneously plans were laid for the development of rubber plantings within suitable areas. The general plan is for the development of small one-man or one-family plantations in regions having the proper soil and being otherwise climatically and economically adapted. It is thought that small-farm rubber cultivation has a far greater chance of success in the Western Hemisphere than would large plantation enterprises, although an interspersion of large and small units is probably most desirable.

The most serious problem relating to the cultivation of *Hevea* in Latin America is the widespread presence of the South American leaf blight, caused by *Dothidella ulei*. This disease is spread through the whole native range of *Hevea* in the Amazon Valley and its further spread to other Latin American areas where *Hevea* can be grown successfully is quite likely. It has been the cause of the abandonment of numerous former attempts to establish rubber plantations in the west. However, in the last ten years or so several disease resistant clones have been developed, mostly in the plantings of the Ford Motor Company begun in 1927 in Brazil, and in those of the Goodyear Tire and Rubber Company begun in 1935 in Panama, and in 1936 in Costa Rica. Further selection of resistant strains for building of clones is one of the goals of the present cooperative program. A discussion of the disease problems and the methods used for overcoming them is given by Rands (1942) in an article regarding the various aspects of Hevea culture in Latin America.

The other aim of the selection and breeding work under way is the development of high-yielding strains. Many of the eastern clones of *Hevea* selected and bred during the last few years have exceedingly high rubber yields. The combination of these high rubber yields with high leaf blight resistance is counted upon to provide superior strains for the new western plantings.

Castilla elastica deserves mention in any roster of the rubber bearing plants, not because it plays any appreciable part at present in the cultivation of rubber but because of the part which it plays as a wild rubber source. It was at one time as important as *Hevea* in the production of natural rubber, and in the late nineteenth century and early twentieth century large numbers of Castilla trees were planted in Latin America.

Castilla, also called, though erroneously, *Castilloa,* is a member of the mulberry family and extends from Mexico southward into Bolivia, Brazil and Peru (Loomis 1942). Rubber is gathered from *Castilla* by tapping, but it differs from *Hevea* by giving a relatively large amount of latex at each tapping, but can be tapped only a few times a year without serious injury. It has been a common procedure to cut large Castilla trees for their rubber yield which may be as much as 50 pounds from one felled tree. *Castilla* has played a large part in the supplying of so-called "wild" rubber during the present emergency.

Guayule, *Parthenium argentatum,* was "discovered" by Dr. J. W. Bigelow of the Mexican Boundary Survey in 1852 "near Escondido Creek, Texas." It was described and named by Asa Gray in 1859. Guayule is native to the North Central plateau region of Mexico extending into the Big Bend region of Texas. Within the area it is confined rather strictly to limestone soils and is generally restricted to altitudes between 3000 and 7000 feet, where rainfall averages from 10-15 inches a year.

A detailed description of Guayule and its characteristics has been published by Lloyd (1911, 1932). Guayule is a member of the Compositae, a low-growing, much branched, woody shrub with small silver-gray leaves. Wild plants are generally about two feet in height, and have a dry weight of one or two pounds after several years growth. Hardy perennials in habit, undisturbed plants probably live some 30 to 40 years. There is occasionally some vegetative reproduction but most of the reproduction is by seed. Under favorable conditions large numbers of seeds are produced, but in very dry periods particularly, seed production is limited. In semi-arid regions to which the plant is native it has great capacity to withstand long continued droughts. However, under drought conditions very little growth takes place.

The rubber in guayule occurs in latex, but in contrast to the situation in *Hevea* and the other so-called latex-bearing plants the latex is not found in vessels or tubes but is a component of the individual parenchymatous cells. Rubber is stored in all parts of the plant except perhaps the leaves. In wild plants the rubber content usually averages around 7% of dry weight for mature plants. Cultivated selected strains run as high as 22% rubber at maturity.

The Germans began experimenting with the extraction of guayule rubber before 1900 but the product remained unimportant until in 1904, a factory, using a pebble-mill extraction process, was set up in Torreon, Mexico. Other factories followed and small-scale production of rubber from guayule has been almost continuous since, except during one period of very low rubber prices.

The supply of wild guayule is strictly limited, however, and, except for the imposition of conservation measures, would have been exhausted some time ago. It is estimated that a constant production rate of 7,000 to 10,000 tons a year would be possible in Mexico without depleting the natural supply.

Any increase in the production of guayule depends upon cultivation of the shrub. Two projects for the furtherance of guayule cultivation were begun in the early days of the war. One of these has been directed toward intensive cultivation of the plant in the United States, largely in California, the other toward a considerably less intensive cultivation in areas of Mexico presenting adapted lands but a vastly different economic picture (Brandes 1942a). The procedures of maintenance, and to some extent those of planting and harvesting, are unlike in the two areas, but fundamentally the problems of domestication are the same.

To begin with germination of guayule seed when and where desired is a difficult accomplishment. In the wild, germination hinges on the presence of large amounts of moisture for the elimination of the inhibitors. Nursery practice consists of chemical treatment of the seed followed by preplanting germination in chambers. The seeds are then mixed with sawdust or sand, and kept very moist until the seedlings are established. Naturally this procedure presents serious problems in disease control. The use of rigid sanitary measures, strict water regulations, and use of resistant strains is dictated. Seedlings are grown in nursery beds usually from March or April until January of the following year. The length of time allowed between transplanting and harvesting depends a great deal upon conditions. At least two years' growth is necessary and maximum rubber content is not reached for many years. The plan for cultivation in California originally called for harvesting the major portion of the plants in the fourth year. Because of the urgency for early production it is planned to harvest much of the area after only two years.

Most interesting of the problems connected with the growth of guayule in the field are those arising from the relation of growth to rubber formation. It was early observed that if conditions for growth are very favorable plants of guayule would grow to a very large size but would contain practically no rubber. On the other hand small, but mature plants often contained large percentages of rubber. Study has revealed that little rubber is formed during periods of active growth, and that if growth has been very good little rubber is formed in a subsequent less active growth period. In guayule the cortical tissue is the main rubber-bearing region. This tissue is laid down, or at least differentiated mostly during periods of slow growth, and only following a general growth phase. A seasonal rhythm of growth and rubber formation has been found and cultivation practices are now directed toward following this rhythm. Attempts are made to produce fairly vigorous growth early in the season and then permit a gradual drying to limit growth by mid-summer.

Rubber is then produced freely during the late part of the season. The procedure calls either for some irrigation during the early part of the season in semi-arid regions, or in California by fitting the time of planting to utilization of winter rains to the greatest advantage.

In the California plantings the small first-year plants grow fairly vigorously all summer by drawing on the winter rainfall. As the plants become larger in succeeding years they exhaust the available moisture, and thus growth is slowed progressively earlier each year, leaving a longer period for rubber formation.

A very marked increase in rubber yield has been secured by selection of high-yielding varieties of guayule. The plants first brought under cultivation ranged, after five years growth, from less than one to over fifteen pounds in weight. All of the large plants were found to be low in rubber content. It is probable that most of the very large plants were progeny from crosses between guayule and *Mariola*, a related and associated plant with a 1 to 2% rubber content. Selection, mostly of medium-sized plants, and the building up of varieties in isolation has now established strains which consistently yield 20% rubber at the end of five years—an acreage yield of something just over a ton of rubber.

Guayule rubber, as extracted from the plant, is a highly resinous product. When deresinated, however, it is a good quality rubber.

Cryptostegia. Rubber from this genus was displayed at the Exposition of Madras in 1856. By crude native methods rubber was produced from *Cryptostegia* growing wild in both India and Madagascar during the nineteenth century.

Cryptostegia grandiflora, the palay rubber vine, was introduced into Mexico as an ornamental by a German sea captain. It spread rapidly in Mexico and then to Florida and the West Indies.

Cryptostegia madagascariensis, the Madagascar rubber vine, was introduced into Florida as an ornamental in the present century. In 1927 a natural hybrid between these two species was discovered in Florida. Detailed descriptions of these two species and the hybrid have been given by Polhamus, Hill and Elder (1934).

Cryptostegia is a much branched shrub or vine which under good conditions, particularly as to soil and moisture relations, makes rapid growth. The latex in *Cryptostegia* is in a latex tube system. It can be obtained by tipping the stems, or by chemical or mechanical extraction from the leaves and stems, though the latter has been done only in experimental studies and is not commercially practical. The rubber secured from stem tipping is superior to that extracted by other means but the yield per stem is extremely small and the amount of labor involved is tremendous.

Cryptostegia for rubber production has been planted over a large acreage in Haiti. The project, originally intended to contain 100,000 acres, is variously estimated as 40,000 to 43,000 acres at expiration of the planting deadline on March 31, 1944.

Goldenrod. The suggestion for the use of goldenrod as a source of rubber goes back to the work of the late Thomas A. Edison (Polhamus 1933). Edison directed a survey of some 17,000 samples of plant material from several different species native to this country. From this survey he decided that certain species of goldenrod represented the most promising plants for a possible development of domestic source of rubber which could be used during an emergency which cut off other rubber sources. At Mr. Edison's death his selected goldenrod material was turned over to the United States Department of Agriculture. Four species, *Solidago altissma, S. gigantea, S. leavenworthii,* and *S. sempervirens* were selected as the most promising.

In cultivation *Solidago leavenworthii,* native to Florida and extending North only to Georgia and South Carolina, has proved most satisfactory as to rubber yields. Selected strains of this species have given indicated yields of from 50 to 75 pounds of rubber per acre in the first year. These selected strains are propagated by stolon cuttings, a method which permits a very large annual expansion.

Limited to certain areas in the South, goldenrod has an advantage in that its soil requirements are not exacting. Average quality sandy loam "cotton land" is quite satisfactory.

At one time in the developmental program the goldenrod scab, caused by *Elsinoe solidaginsis,* presented a serious problem, but the better selected strains are almost completely immune. Goldenrod is harvested in the fall of the year by mowing and the leaves or the leaves and the stems are utilized for extraction of rubber. Extraction has been generally successful only by solvent processes. There is a possibility that the ligno-cellulose leaf residues, some carbohydrates and some proteins may provide by-products.

Taraxacum kok-saghyz, better known simply by its descriptive species name, which means "chew-root" in the Kazak language of its native habitat, is a comparatively new addition to the roster of potentially important rubber-bearing plants (Brandes 1942b). It was discovered in 1931 by a Russian expedition sent out to collect native Russian plants with a view to cultivating them as a nucleus of a domestic rubber supply. The plant was found at an altitude of 5,500 to 6,500 feet in soil designated as somewhat saline. Stands of about 5,000 acres were reported. The temperature of the region ranges, according to reports, from –2° F. to +59° F.

When grown under favorable conditions, kok-saghyz looks much like our native dandelions. It is distinguished by the character of its involucral bracts and by the shape and size of the leaves.

The Russians began to cultivate kok-saghyz shortly after its discovery by the Ketman expedition. They achieved some considerable measure of success although its domestication in Russia, as in this country, has involved many problems.

A shipment of kok-saghyz seed arrived in this country in May 1942 and was distributed to various cooperating agencies and stations of the Bureau of Plant Industry for planting. Work of the last two years has indicated that kok-saghyz can be grown successfully in certain areas within this country and that with the solution of certain fundamental problems the plant would represent a valuable source of rubber.

As to its distribution it is now apparent that good growth of the plant in cultivation can be secured during the summer only in regions far enough north so that they do not have continued periods of exceedingly high temperatures. The best growth is of course in regions having relatively, not excessively, high day temperatures alternating with low night temperatures. Within this country the areas around Lake Champlain, in Northern Vermont, the Saginaw Bay area of Michigan, and the Red River Valley of Minnesota have been found to give very good results as to root growth. Best seed yields have been obtained at high elevations in intermountain Rocky Mountain valleys in Montana.

The Russians have reported 27 to 30 pounds per acre of seed as representing excellent yield. Montana yields are in excess of 150 pounds per acre. Some of the plants in that region have shown as many as 500 flowers during a season with as many as 100 in bloom at one time.

The problems incident to cultivating kok-saghyz include many of fundamental biological interest. Plantings grown from the seed which was imported from Russia contained plants ranging in rubber content from tenths of a percent to 16 or 18 percent, and in the case of some Canadian grown material up to 29 percent in the second year. Such a situation offers a tremendous opportunity for improvement by selection. Improvement by selection alone necessitates the building up of clones of the selected material by vegetative propagation.

Vegetative propagation of kok-saghyz has presented numerous problems for solution. Early experiments with root cuttings in the greenhouse tended to indicate that the matter of making root cuttings and growing plants from them was fairly simple. Attempts to repeat the procedures in the fields were very unsuccessful. Several factors now seem to be concerned. In the first place the amount of available stored nutrient material is a controlling factor. There is a wide variation in the amount of this material in different parts of the seasonal cycle. It now looks as though root cuttings would either have to be made at certain specific times in the plants' growth cycle, or that roots would have to be stored at temperatures low enough to control the utilization of nutrient materials until the cuttings are made.

Kok-saghyz root segments are very strongly polarized with reference to the initiation of root primordia. As a result it seemed at first to be necessary to plant all the cuttings in their normal vertical positions. More recent work indicates that if the cuttings are placed horizontally, there occurs an apparent displacement of growth substances which induce the formation of many adventitious roots on the lower side of the cutting, and rapid rooting results. Many other problems, including that of disease control are involved in vegetative propagation.

Breeding work with kok-saghyz is complicated by the same factor which makes for the tremendous amount of heterogeneity in the populations. The plant is almost, if not completely, self-sterile. One would expect, of course, that a thorough study of populations would reveal the presence of a group of sterility factors operating in such a way as to isolate given genetic blocks of plants. There is some indication that this condition prevails. There is also a suggestion that there is a certain amount of self-fertility during particular periods of the blooming cycle. At any rate the populations are extremely heterozygous.

Two courses suggest themselves for obtaining more homozygous material. A search may reveal, as it has in many plants, certain individuals with a genetic factor for self-fertility. There is a possibility that such a factor could be combined with otherwise desirable characters. Another approach is to make crosses of such a nature as to put into the progeny a factor for apomixis which is common in other species of *Taraxacum*. Incidentally attempts at crossing *T. kok-saghyz* with other species of *Taraxacum* have brought out the fact that it is diploid while certain other species are tetraploid with respect to the basic chromosome number.

The chromosome number of *T. kok-saghyz* has been doubled by colchicine treatment and some apparently successful crosses between it and *Taraxacum megalorrhizon,* a species with a very high rubber content and some other desirable features, have been made.

Field cultivation of kok-saghyz presents another whole series of problems. First there is, at least in seed more than a few months old, a seed dormancy which must be overcome to secure uniform germination. Not surprisingly, in view of the heterogeneity of the seed stocks, germination of some seed takes place immediately, while that of others may be delayed for weeks or even months.

Planting of the seed in the field must be done with great care, particularly with reference to depth of planting in relation to the soil type. The young seedlings are extremely weak and will not emerge if any soil crusting takes place. Once planted a serious problem arises from the fact that growth of the seedlings is so slow that weeding must ordinarily be done at least once before the seedlings are large enough to distinguish from weeds, or even up so as to permit detection of the rows. Attempts have been made to overcome this difficulty by using transplants and root cuttings. However, the solution probably lies in careful cultivation practices and the selection of more vigorous, more uniformly germinating stock.

Kok-saghyz is harvested by digging the roots after removal of the tops. The roots are then dried and the rubber is extracted by milling the dried roots. The extraction process is simple and inexpensive and the rubber obtained, according to all tests made to date, is of excellent quality, comparing favorably with good grade Hevea sheet.

The utilization of two by-products is possible. The roots contain at harvest time upwards of 8% inulin. The extraction and utilization of this carbohydrate will, according to Russian work, pay for the processing cost of the rubber. In addition 7 or 8% pectin is contained in the roots and its utilization has been suggested.

Other Plants. Many other plants yield rubber, some of them in appreciable amounts, but the ones mentioned seem to offer the only possibilities as rubber sources in the Western Hemisphere. Mention ought to be made, perhaps, of the fact that Russians have actually grown small plantings of certain species of *Scorzonera* for rubber production.

The Canadian Department of Agriculture is experimenting quite extensively with one of the milkweeds, *Asclepias syrica*. A suggested procedure here, however, is not to attempt to extract rubber itself, but to extract the rubber and resin compound from the leaves and utilize it as a combining agent with various synthetics.

Conclusions. It is perhaps of interest to attempt to gain as comprehensive a picture as possible of the parts played by this work on rubber plants in the present emergency and in the economic and social picture of the future. We were, at the end of 1941, cut off abruptly and almost completely from our source of a material which has come to play a very large part in our lives, both in war and in peace. We had on hand a rather limited supply of that material. The Rubber Conservation Program and the rapid and successful development of the synthetic rubber industry has turned the trick to the extent of preventing a complete breakdown in essential military and civilian transportation and in other processes so dependent upon rubber.

In 1941 it was imperative that we investigate all possible sources of natural rubber even though it was readily recognized that many of them could contribute very small amounts of rubber at a very high cost per pound. This was insurance against the possibility that for one reason or another the synthetic rubber program might not be developed as rapidly and as well as it has.

In 1944 continued research on the minor rubber yielding crops is of importance—first, because some of them hold real potentialities for development as natural rubber sources, and because studies of all of them yield data which are of value in work on the more important ones. There is a considerable amount of controversy with reference to the performance of synthetics in automobile tires. There seems to be ready admission of the fact that in large bus and truck tires and those for military vehicles which must travel over very rough terrain, synthetic rubber is unsatisfactory unless it is combined with a large proportion of natural rubber and even then the product is not as good as a pure natural rubber tire. We have been using natural rubber from a stock pile which was none too large at the beginning of the war and which has been diminishing very rapidly.

In his last report the Rubber Director estimated that our imports of natural rubber during 1943 would total 60,000 tons.

Recent directives have been issued from the Office of the Rubber Director and the War Production Board further curtailing the use of natural rubber.

The manufacture of synthetics from petroleum products is based on the use of materials of which, even now, there are predictions of exhaustion of supplies. The manufacture of synthetics from alcohols involves growing plants for the production of carbohydrates, fermenting the carbohydrates, and then by complex processes producing a rubber substitute. Even if the synthetics prove to be as good as natural rubber this procedure must compete economically with a product formed directly by the plant.

Add to all of this the fact that consumption of rubber is undoubtedly going to increase very markedly after the war, when a tremendous deficiency of tires and other rubber articles will have to be filled, and there would seem every justification for very strong continued emphasis on the development of sources of natural rubber in the Western Hemisphere. Of these sources *Hevea brasiliensis* is most important and guayule has good possibilities. Kok-saghyz holds a potential rubber yield of perhaps 400 pounds per acre, the attainment of which presupposes the solution of several biological and production problems. It has the added feature of being the only crop from which good rubber can be obtained in a very short period.

Continued research on all of these crops is yielding valuable information, not only for rubber production, but for the production of other crops as well. In addition the development of the Hevea project is laying the basis for a more complementary trade with our Latin American neighbors after the war.

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Literature Cited

BRANDES, E. W. 1941. Rubber on the rebound—East to West. Agric. in the Americas. **1**: 1–11.

———, 1942a. Go Ahead, Guayule! Agric. in the Americas. **2**: 83-86.

———, 1942b. Rubber from the Russian dandelion. Agric. in the Americas. **2**: 127–131.

LLOYD, FRANCIS ERNEST. 1911. Guayule (*Parthenium argentatum* Gray) a rubber-plant of the Chihuahuan Desert. Carnegie Institution of Washington. Pub. 139: viii+213. Illus.

———, 1932. Mode of occurrence of caoutchouc in the guayule, *Parthenium argentatum* Gray, and its function. Plant Physiology **7**: 131-138, 1932.

LOOMIS, HAROLD E. 1942. Castilla rubber's comeback. Agric. in the Americas. **2**: 171-176.

POLHAMUS, LOREN G. 1933. Rubber contents of various species of goldenrod. Jour. of Agric. Res. **47**: 149–152.

———, H. H. HILL AND J. A. ELDER. 1934. The rubber content of two species of *Cryptostegia* and of an interspecific hybrid in Florida. USDA Tech. Bull. 457: 1–23.

RANDS, R. D. 1942. Hevea rubber culture in Latin America. India Rubber World. **106**: 239–243, 350–356, 461–465.

WOLF, H. AND R. 1936. Rubber. xii+533 p. New York.